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EFFECTS OF BODY AND HAND COOLING ON COMPLEX MANUAL PERFORMANCE

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12 United States Army enlisted men were tested on 3 manual tasks, knot-tying (KT), block-stringing (BS), and block-packing (BP), under 4 conditions: (a) Control—Mean Weighted Skin Temperature (MWST) 90.0° F., Hand Skin Temperature (HST) 93.0° F. (b) Cold Body—MWST 69.0° F., HST 90.4° F. (c) Cold Hand—MWST 85.8° F., HST 45.7° F. and (d) Cold Hand-Body—MWST 68.5° F., HST 45.8° F. The 3 cooling conditions had a differential effect across the 3 tasks. Cold Body was the only condition that did not result in significant decrements for all tasks. Knot-tying was unaffected by body cooling. The results were interpreted in terms of the differential effect of cooling the hand or body upon various aspects of complex manual performance.

Gaydos (1958), in investigating the effect on complex manual performance of lowering body surface temperature (BST) and either lowering hand skin temperature (HST) or maintaining normal HST, found significant manual performance decrements when HST was lowered. He concluded that during cold exposure HST, but not BST, is a vital factor in maintaining maximum efficiency in the performance of a complex manual task. Gaydos and other investigators (Gaydos & Dusek, 1958; Clark, 1961) have found that manual performance is impaired during cold exposure when HST drops to 55 degrees F. and below.

The purpose of this study was to compare the roles of HST and BST in complex manual performance using a lower BST than that tested by Gaydos. It was expected that lowering either BST or HST would affect manual performance, but that each of these two cooling conditions would affect different aspects of manual performance.

Method

Subjects. Twelve Army enlisted men were divided into four groups of three subjects (*S*s) each with each group receiving all four treatment conditions in a different sequence. One *S* was unable to complete the study.

Apparatus and procedure. All tasks were performed inside a 3 feet 6 inches × 3 feet × 2 feet 8 inches thermostatically controlled hand box with a temperature range of −30 degrees F. to 140 degrees F. The *S*s, seated in front of the box, reached the tasks through two arm holes and viewed the tasks through a window. The hand box was located inside a temperature controlled chamber with a range of 0 degrees F. to 160 degrees F.

Three manual performance tasks were used: knot-tying (KT), block-stringing (BS), and block-packing (BP). For the KT task *S* was required to tie one "overhand knot and bight" on each of a number of strings hanging from the edge of a horizontal, rotatable disk. The BS task involved stringing small blocks with holes through each face onto a needle and string. The BP task consisted of packing small blocks in rows along the floor of a box with one hand while holding the box in the other.

All *S*s received 10 training trials per day on each of the 3 tasks for 5-consecutive days. A trial was defined as stringing 20 blocks, tying 15 knots, or packing 30 blocks. Each day during training the order of task presentation was determined randomly for each *S*. After training, each *S* was tested on 4-consecutive days, that is, a control day and 3-experimental days. The order of task presentation was counterbalanced daily across the three *S*s in each sequence. The performance measure was the mean number of units completed over four 30-second trials. A 30-second intertrial interval was used throughout both phases.

On all test days *S*s wore only shorts, socks, and boots. The following test conditions were used:

Control—Mean Weighted Skin Temperature (MWST) of 90.0 degrees F. and HST of 93.0 degrees F.

Cold Body—MWST of 69.0 degrees F. and HST of 90.4 degrees F.

Cold Hand—MWST of 85.8 degrees F. and HST of 45.7 degrees F.

Cold Hand-Body—MWST of 68.5 degrees F. and HST of 45.8 degrees F.

Ambient temperatures of 40 degrees and 80 degrees F. and box temperatures of 0 to 10 degrees F. and 90 to 110 degrees F. were used to obtain the above conditions. Air movement at speeds up to 15 miles

TABLE 1

EFFECT OF COLD HAND, BODY CONDITIONS ON MANUAL PERFORMANCE

Task	Control	Cold body	Cold hand	Cold hand-body
KT	20.32	19.64	14.75	11.77
BS	18.68	16.27	14.30	12.82
BP	29.77	27.16	25.34	22.00

Note.—The Tukey multiple-comparison test (Ryan, 1959) was used in the above comparisons. The scores are the mean number of task components completed in 30 seconds. The differences between scores within each task that are not underlined are significant ($p = .05$).

per hour was used during all cooling conditions to help stablize hand- and body-surface temperatures and to obtain the appropriate MWST and HST within a 20-minute exposure period.

Skin temperature measured with copper-constantan thermocouples and rectal temperatures measured with thermistor catheters were recorded by Leeds-Northrup speedomax recording systems. The MWST was recorded simultaneously from 10 points on the body by a multipoint temperature-recording system containing an automatic integrator. The skin temperature from the little finger of the right hand (HST) was recorded by a separate temperature-recording system. All recordings were taken throughout each test period.

RESULTS AND DISCUSSION

The data for each task were analyzed according to Latin-square analysis of variance designs with the four skin temperature conditions being assigned Latin letters. Subjects/Sequence (KT: $F = 4.46$, $p < .005$; BS: $F = 5.87, p < .005$; BP: $F = 3.56, p < .025$) and skin temperature conditions (KT: $F = 46.20, p < .001$; BS: $F = 30.87, p < .001$; BP: $F = 20.30$, $p < .001$) were significant main effects for all three tasks. Sequence was a significant effect ($F = 5.30$, $p < .05$) only in the analysis of the BP data. The mean scores for each task and for each condition are presented in Table 1.

Gaydos (1958), using a MWST of 78 degrees F., failed to find an effect of body cooling on KT and BS performance. The Cold Body condition of the present study (MWST 69.0 degrees F., HST 90.4 degrees F.), however, did result in significant performance decrements in BS and BP.

The Cold Hand condition (MWST 85.8 degrees F., HST 45.7 degrees F.) resulted in KT and BS scores significantly lower than those found under the Cold Body condition. Therefore, although body cooling was found to affect certain manual performance tasks, the role of HST in manual performance is emphasized once again.

The KT and BP scores for the Cold Hand-Body condition (MWST 68.5 degrees F., HST 45.8 degrees F.) were found to be significantly lower than the KT and BP scores found for the Cold Hand condition.

In exception to the above analysis, an examination of Table 1 reveals that, for all tasks, manual proficiency decreased as BST, HST, and then BST and HST were lowered. It is felt, however, that the Cold Body condition affected only the BS and BP tasks, even though this finding is based on a small sample. Thus, together with the conclusion that the hands must be protected from cold exposure for successful manual performance, it is suggested that if the hands are kept warm and the body is allowed to cool to a MWST of 69 degrees F., performance decrements will occur in manual tasks requiring accurate placement or threading of objects (BP and BS). It is suggested, also, that cooling the body while maintaining normal HST does not affect performance of tasks involving only wrist-finger speed and dexterity (KT).

The present study emphasizes the need for further studies to investigate the effect of cold exposure upon complex manual performance by differentiating among the psychomotor components essential to successful manual performance and by testing the differential effects of body surface cooling, hand surface cooling and deep hand cooling upon those components of manual performance.

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